

# A Comprehensive Simulation-Based Framework for Design of Army Ground Vehicles

G.M. Hulbert, Z.-D. Ma, Y. Hahn, G. Ryu

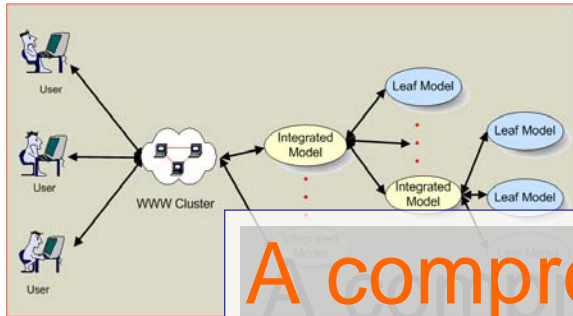
2007 SAE World Conference

April 16, 2007



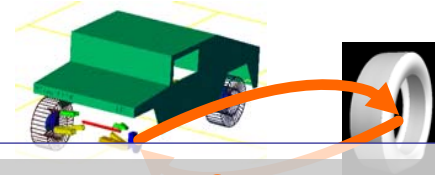
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# Presentation Overview

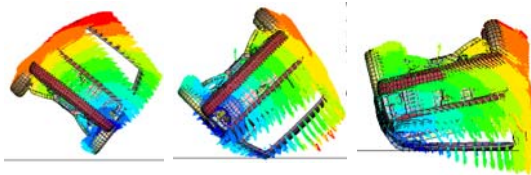
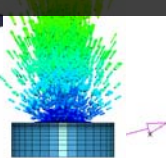


Distributed  
& Design Platform

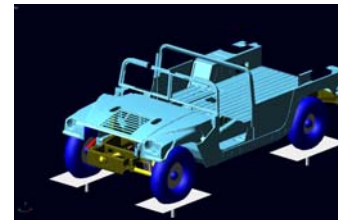
A comprehensive framework for supporting analysis and design of Army's current and next generations of tactical vehicles



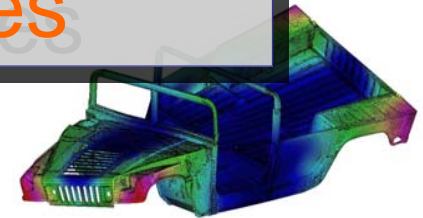
Blast



Crash



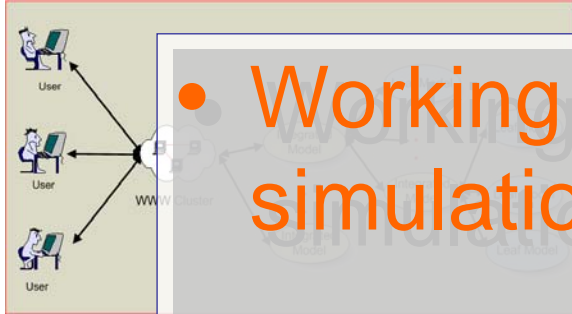
Rollover



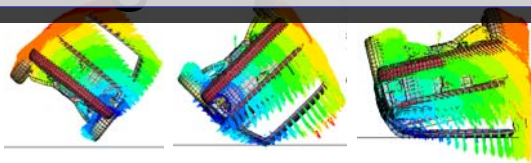
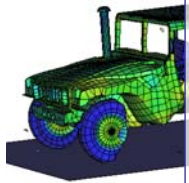
Durability and Ride

# Presentation Overview

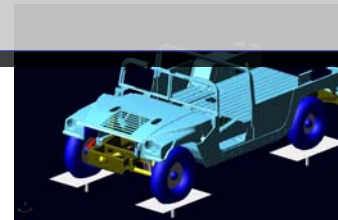
- Working capability for distributed simulation across multiple domains
- New modeling capability for rapid configuration of HMMWV variants
- New modeling techniques for accurate, efficient simulation and design



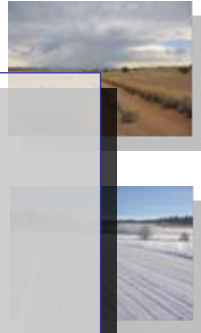
Distributed  
& Design Platform (D-Sim)



Crash



Rollover



Durability and Ride



# Research Objectives

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- Develop an integrated simulation and design capability to support:
  - Modularized product development of current and future vehicle families

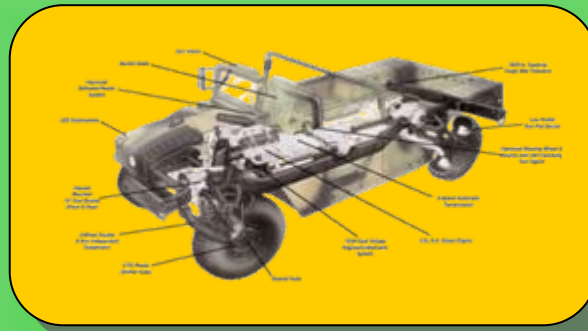
# The HMMWV Family



Fire Fighting



Recoilless Rifle



Hardtop Cargo



Armored Square Back

# Research Objectives

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- Develop an integrated simulation and design capability to support:
  - Modularized product development of current and future vehicle families
  - Innovative vehicle concepts in support of Army transformation

# Future Tactical Truck System



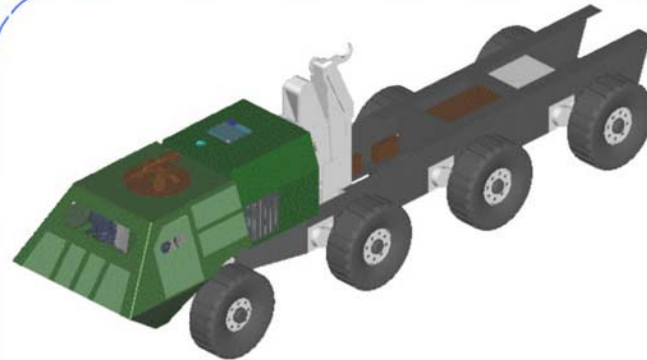
**FTTS MS TUAV Carrier**



**FTTS MS FRMV/Wrecker**



**FTTS MS Water Tanker**



**FTTS MS Common Chassis**



**FTTS MS Fuel Tanker**



**FTTS MS Fuel Station**

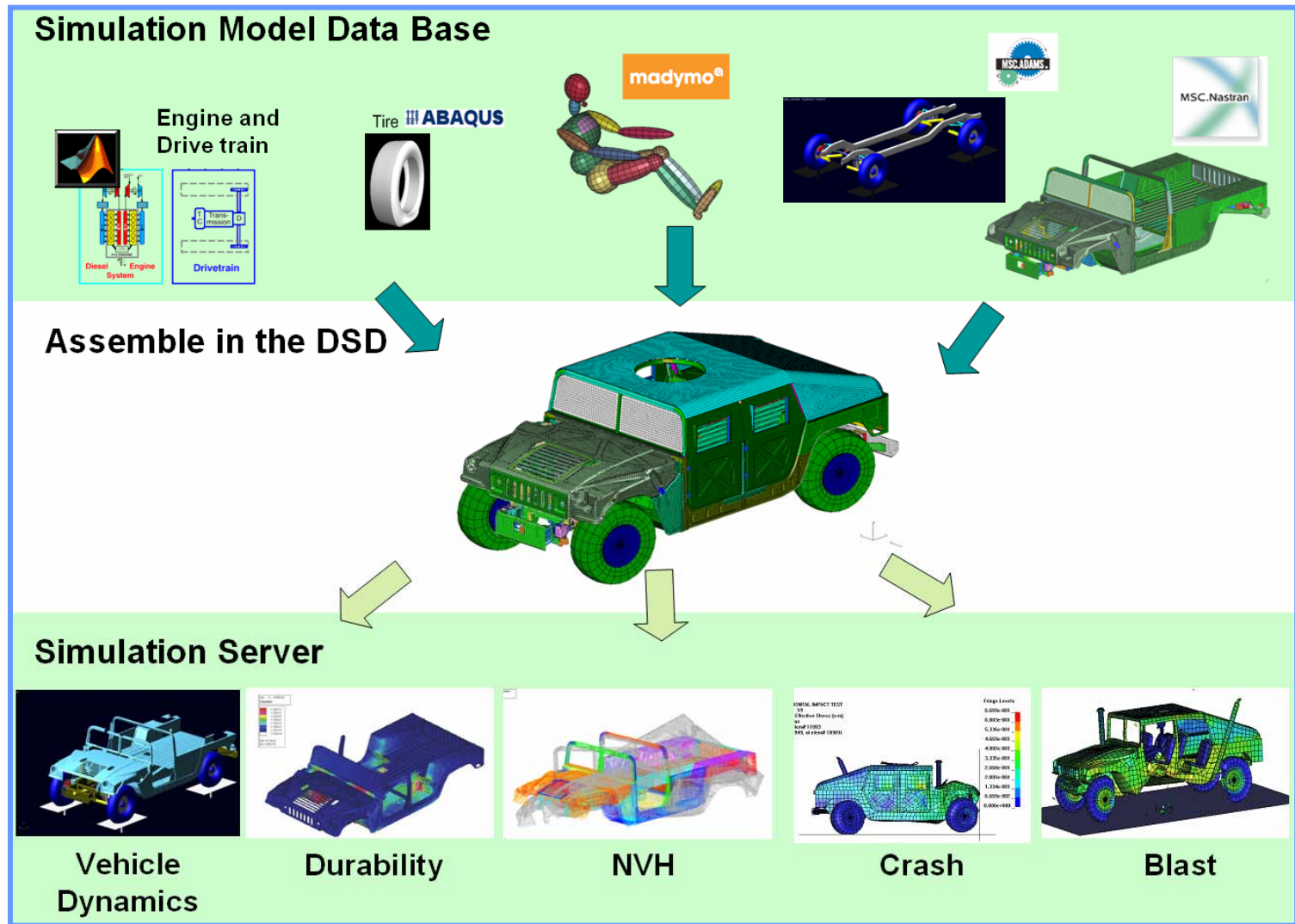
# Research Objectives

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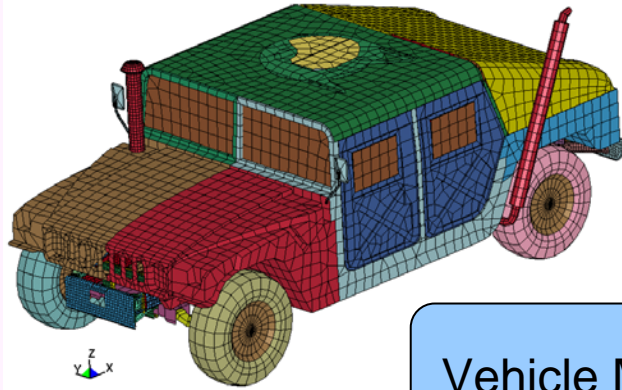
- Develop an integrated simulation and design capability to support:
  - Modularized product development of current and future vehicle families
  - Innovative vehicle concepts in support of Army transformation
  - Efficient integration of distributed models, simulation codes, and new design methodologies for commercial and military applications



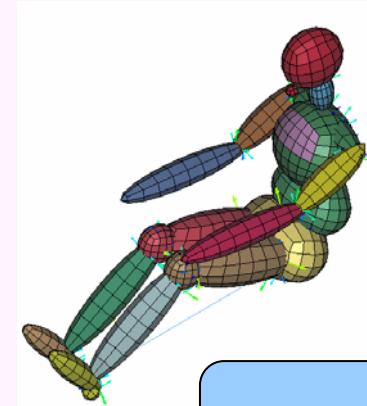
# Vision of Distributed Simulation and Design



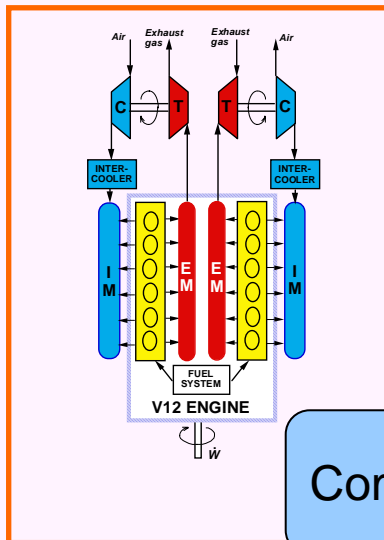
# Requirement: Multi-Domain Simulation



Vehicle Model

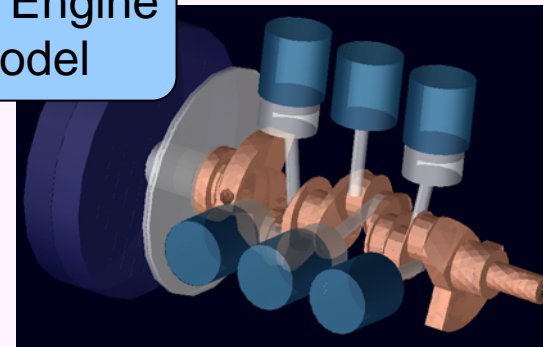


Human Model

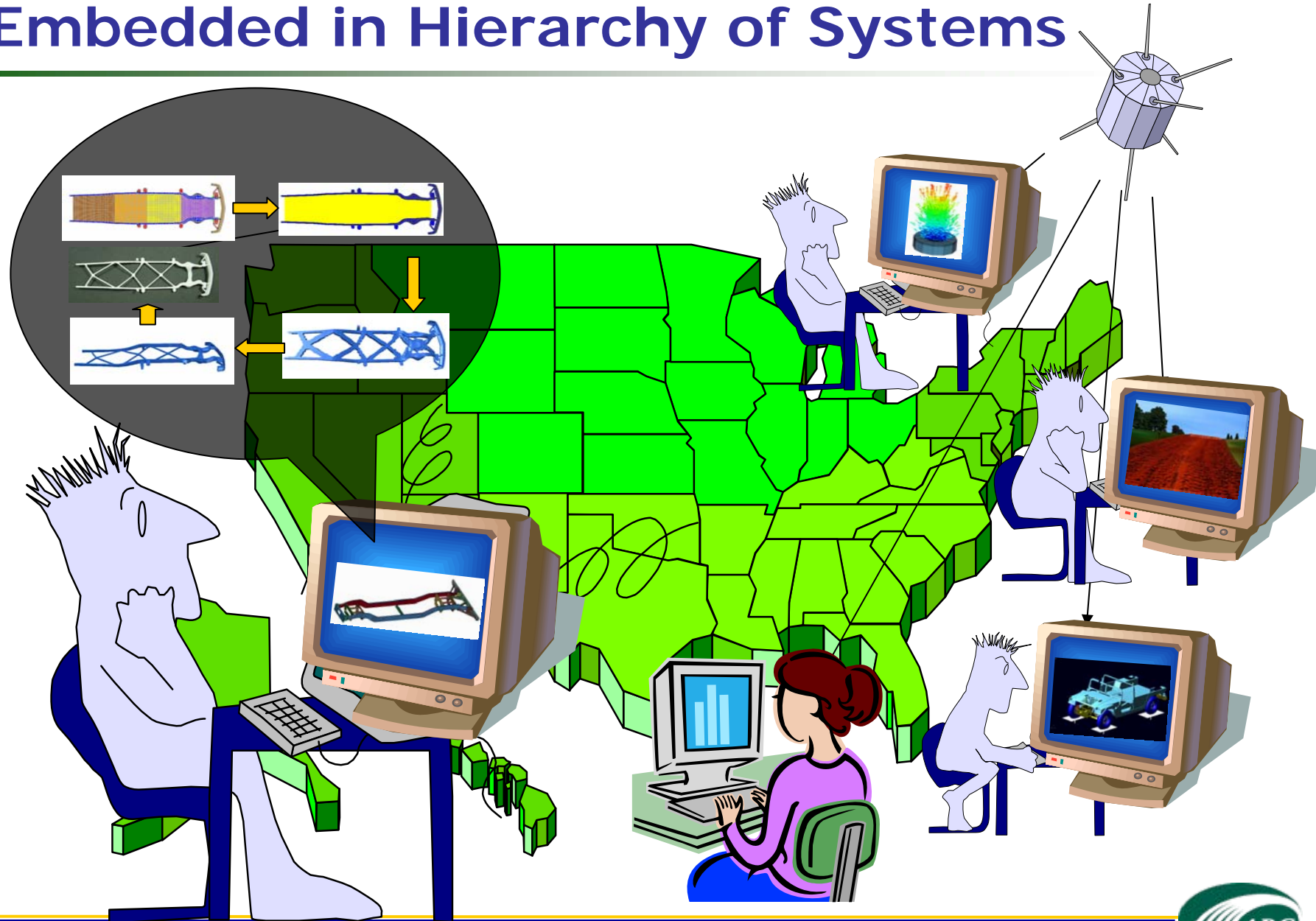


Combustion Model

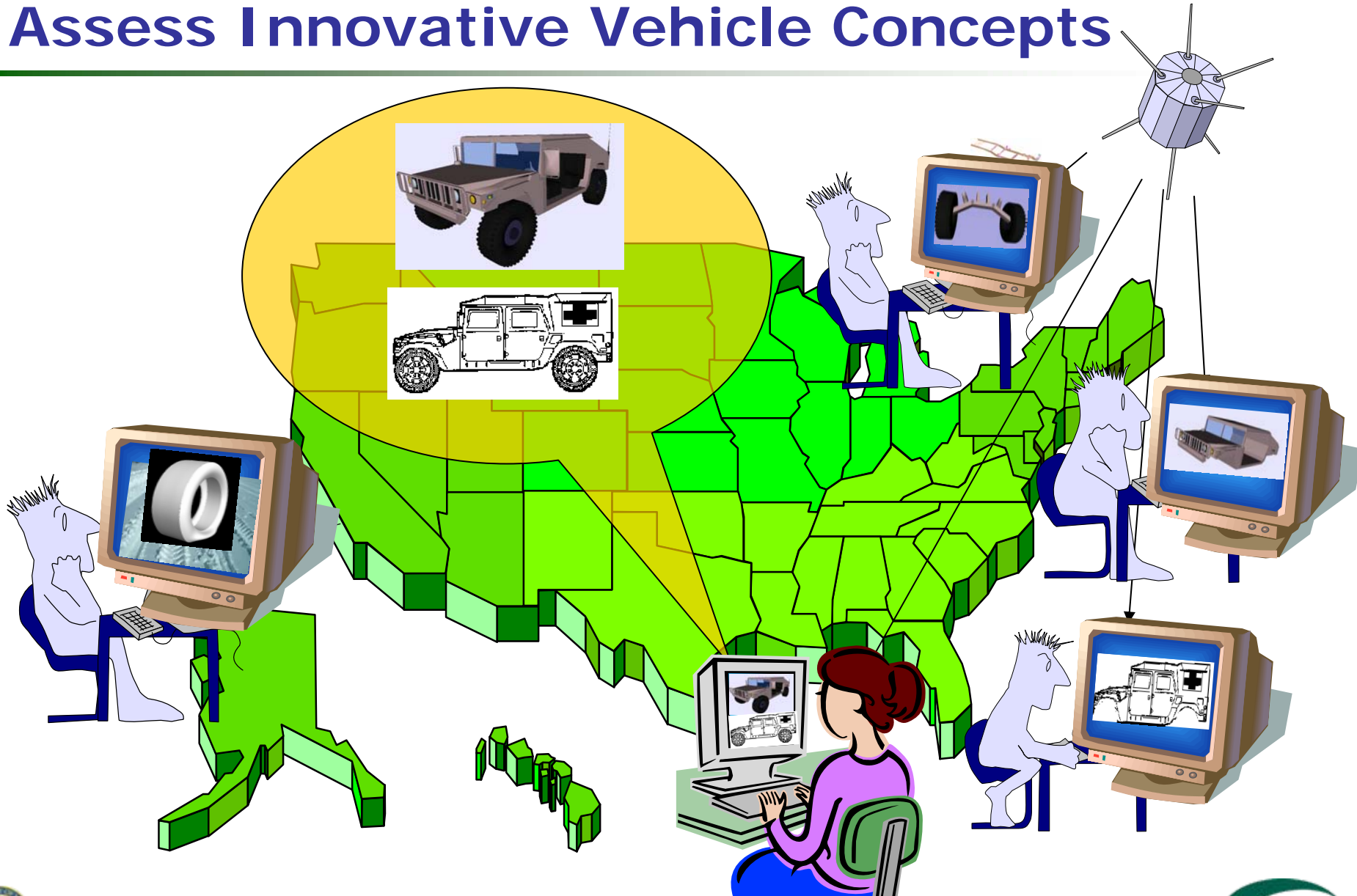
MBD Engine Model



# Requirement: Subsystem Design Embedded in Hierarchy of Systems

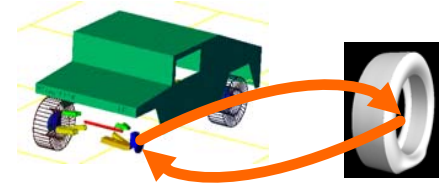
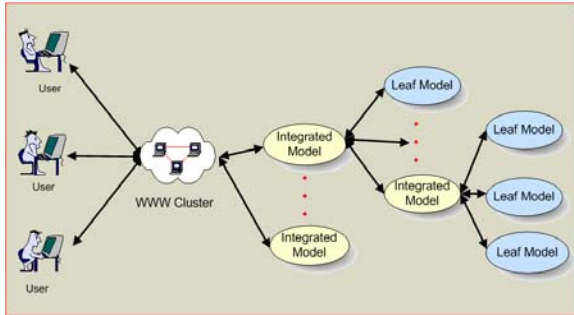


# Requirement: Rapid Configuration to Assess Innovative Vehicle Concepts





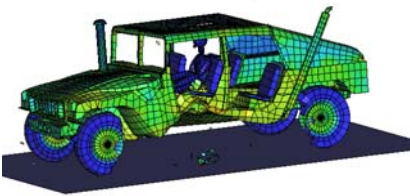
# Overview



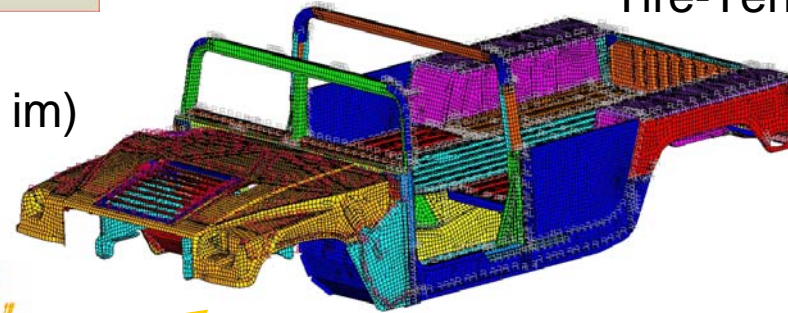
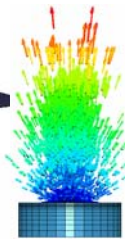
Tire-Terrain Interaction



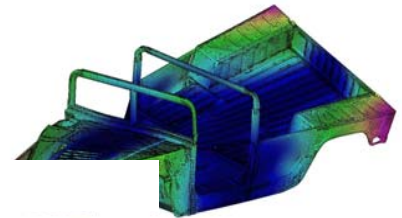
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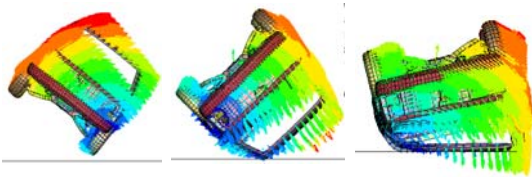
Blast



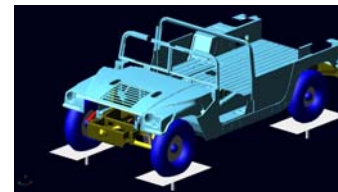
**Distributed Simulation  
& Design Platform (D-Sim)**



Durability and Ride



Crash

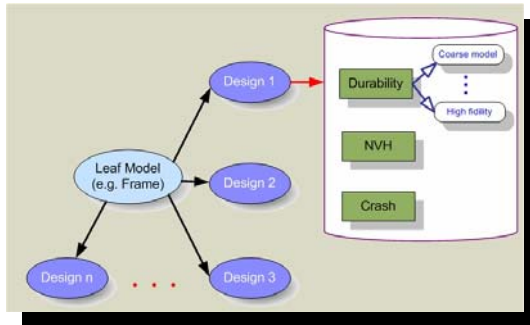


Rollover

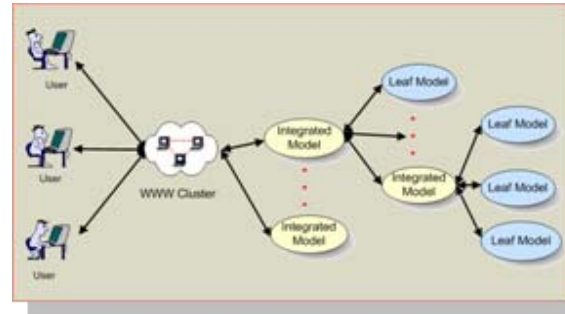


# Major Components of D-Sim

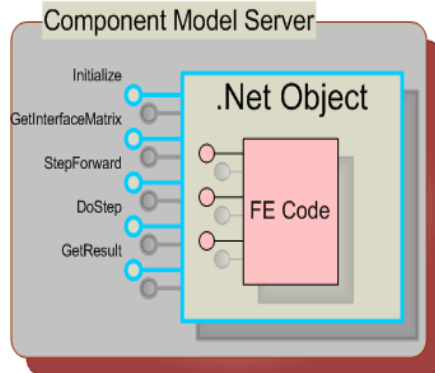
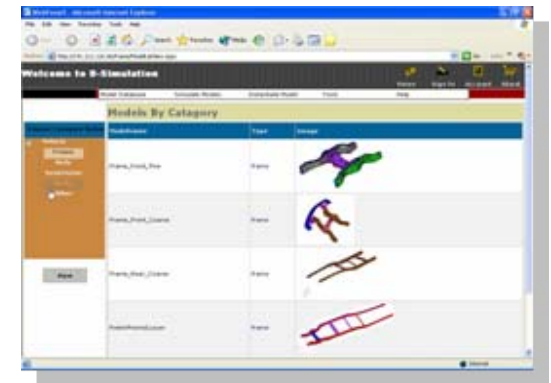
## Model Database



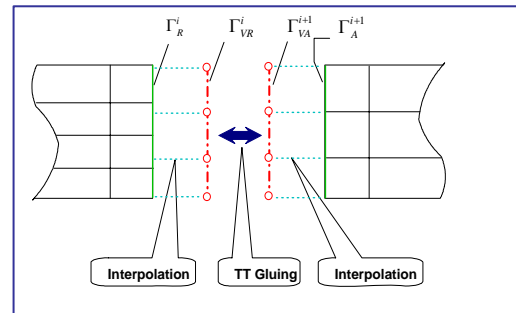
## Distributed Architecture



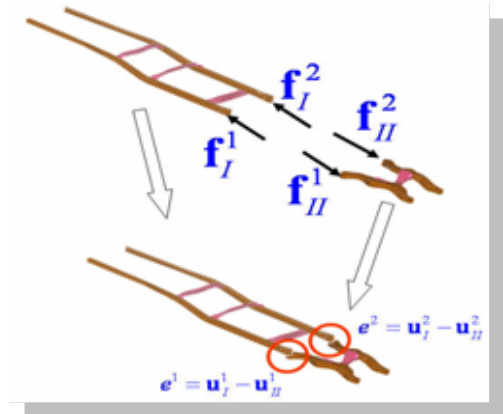
## Web-based Interface



## Simulation Code Wrapper



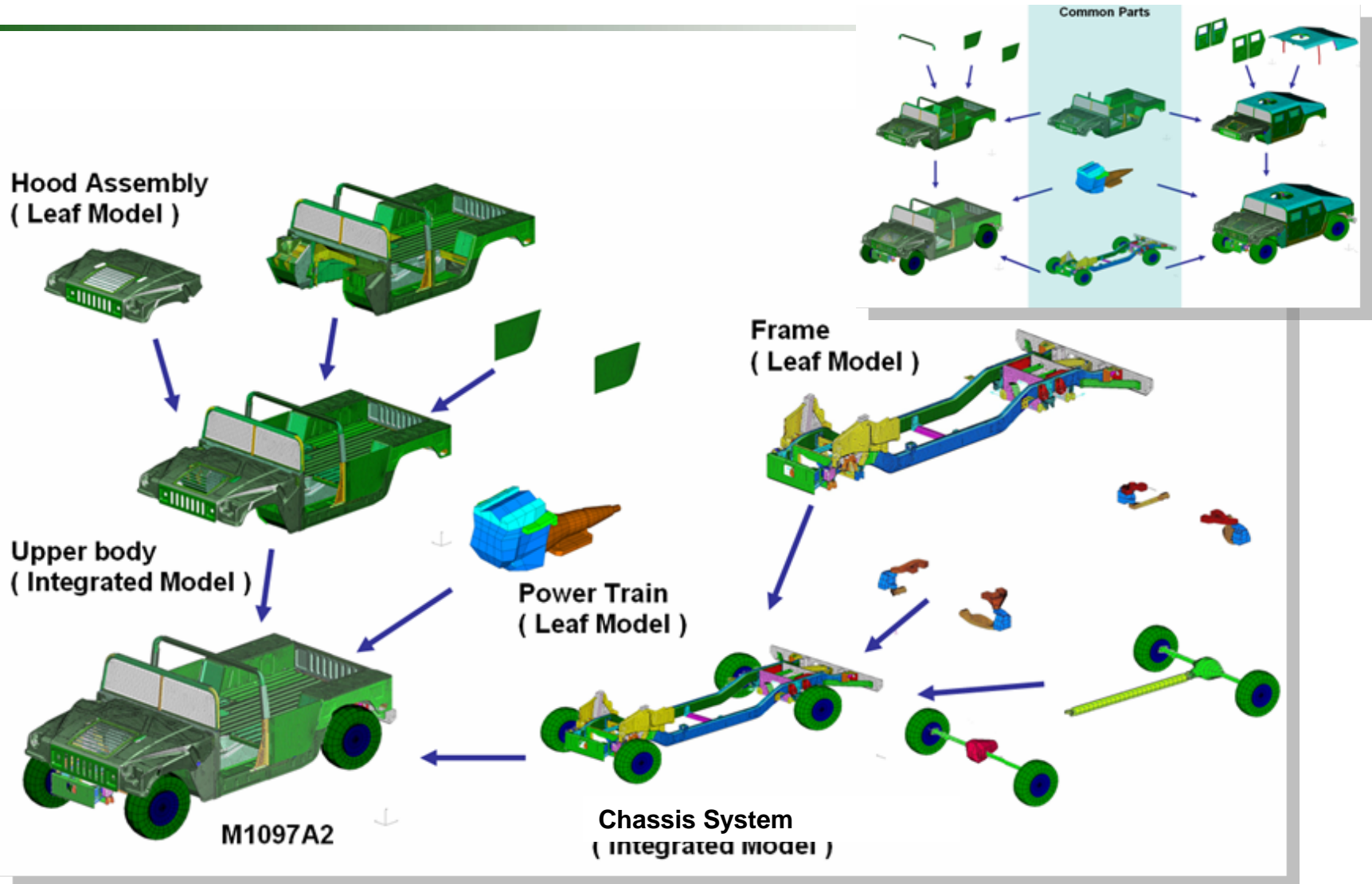
## Non-matching Interfaces



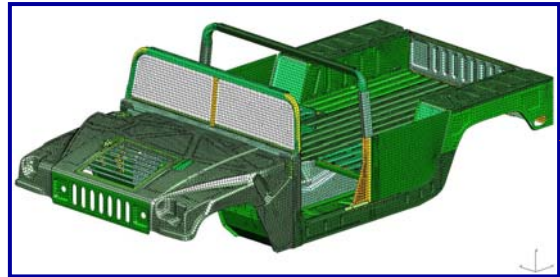
## Gluing Algorithm



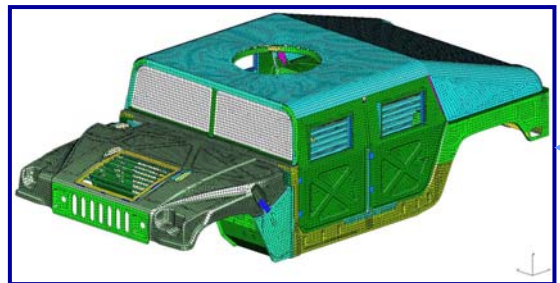
# Integrated Systems Approach



# Rapid Configuration of Different Vehicles



M1097A2 UPPER BODY

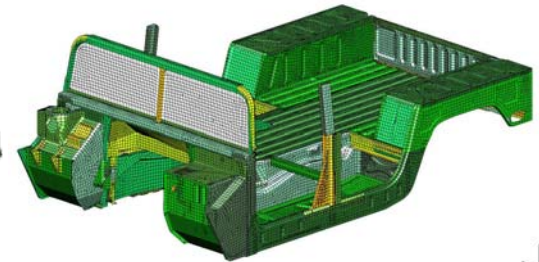


M1025 UPPER BODY

## Common Parts



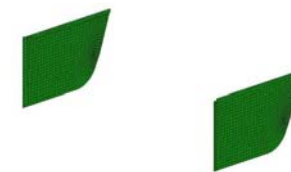
HOOD ASSEMBLY



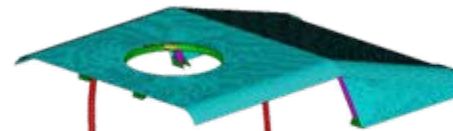
HMMWV BASE UPPER BODY



B-PILLAR  
CROSS MEMBER



RR DOOR



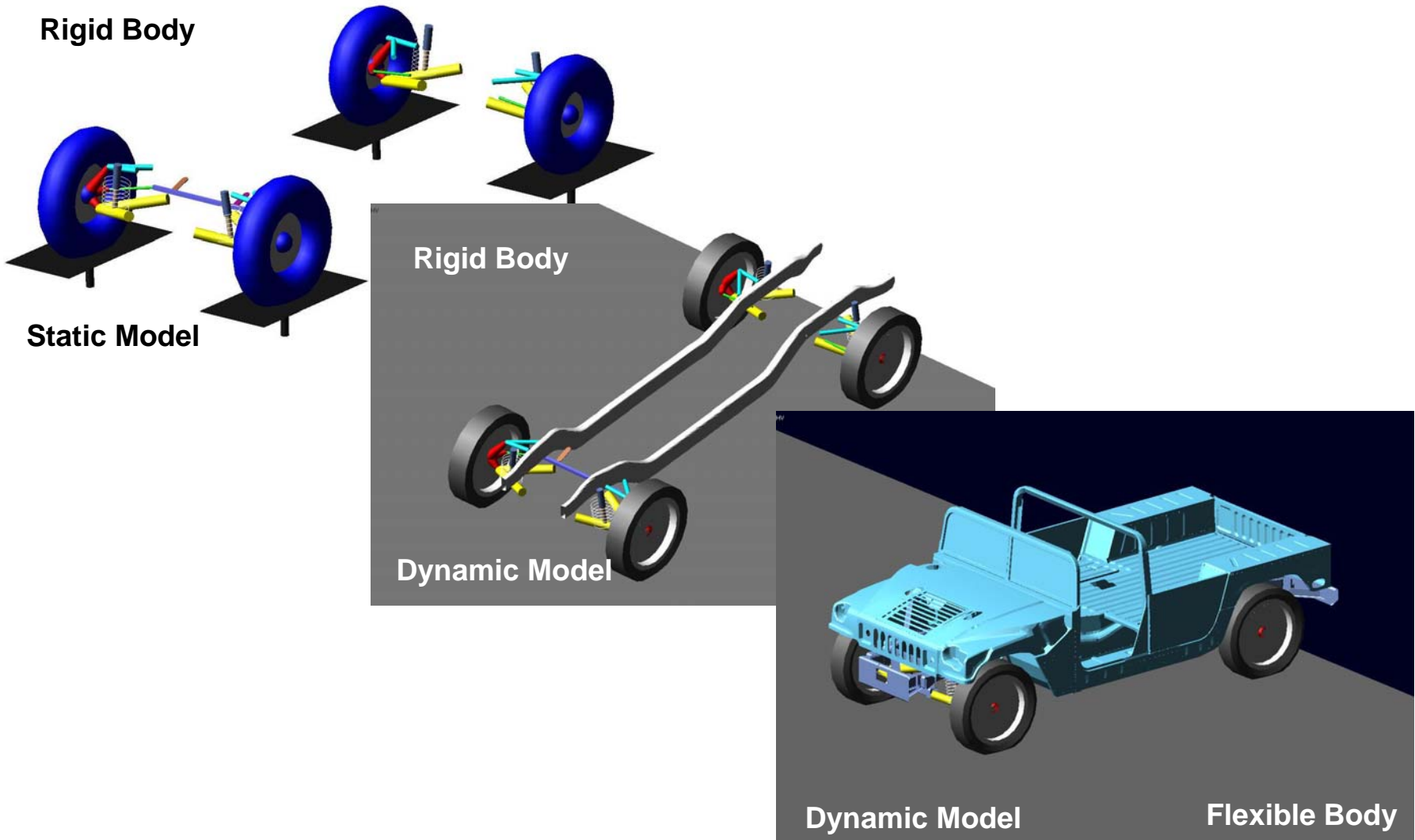
ROOF ASSEMBLY



DOOR  
ASSEMBLY



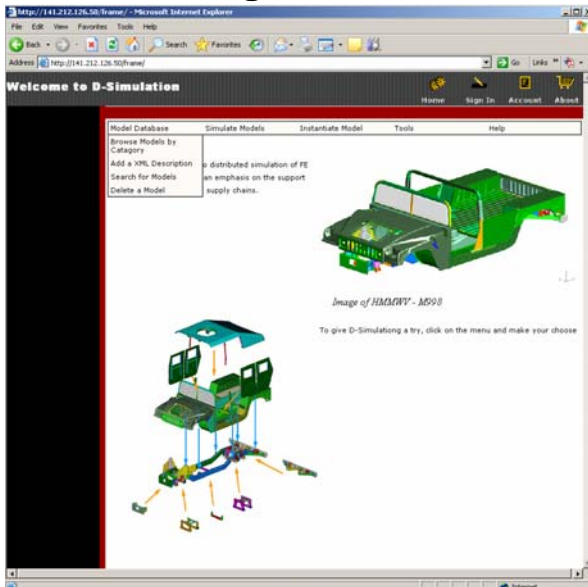
# Rapid Substitution of Different Fidelity Models





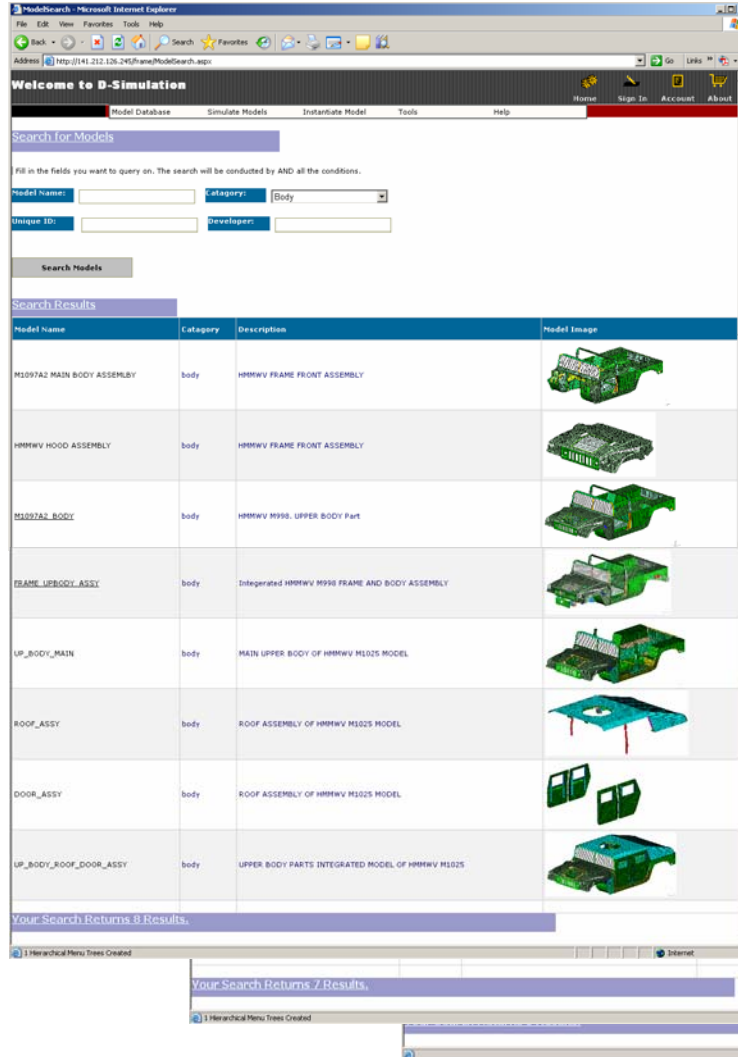
# Web-Based Interface

## Main Web Page for D-Simulation

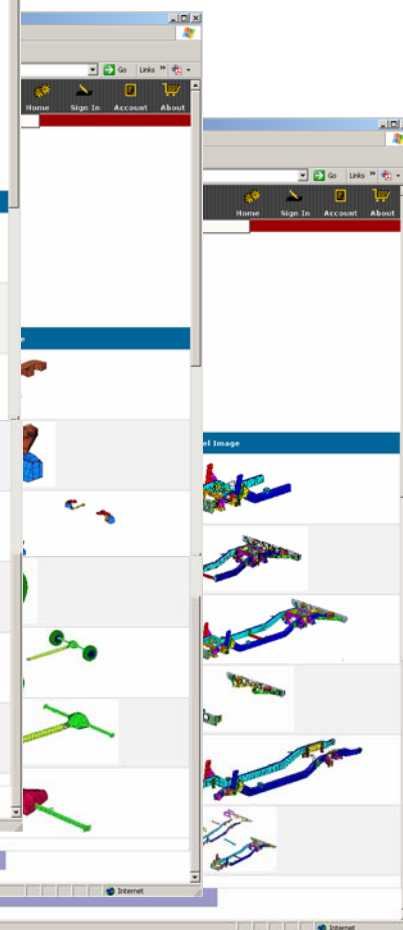


- Search multi-layered model database
- Define interfaces for model integration
- Generate new distributed simulation and design models

## UPPER BODY PARTS

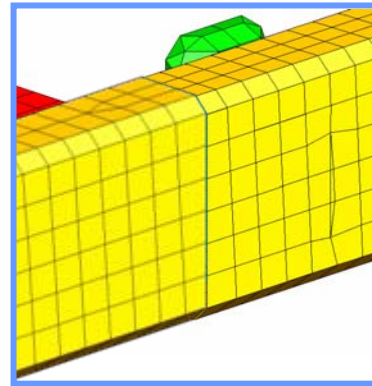
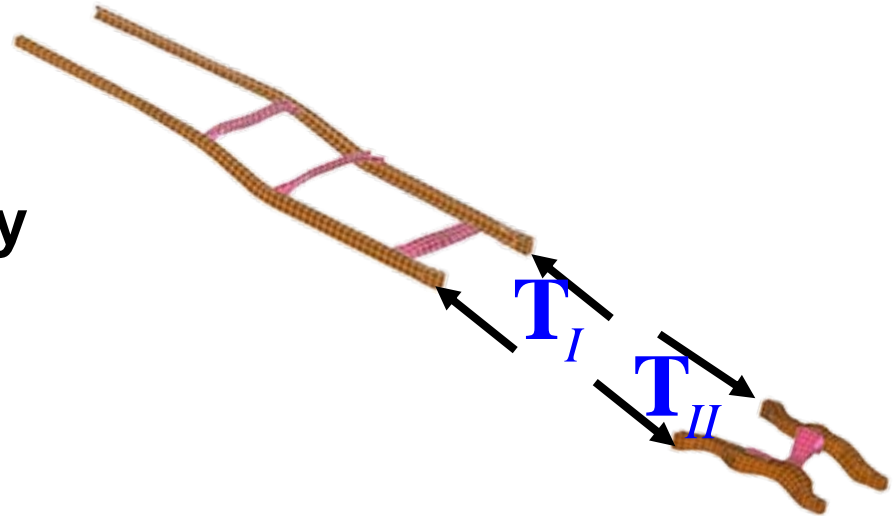


ARTS

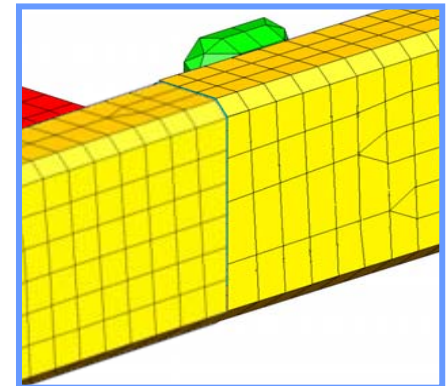


# Gluing Algorithm and Non-Matching Interfaces

- Enables multi-platform, multi-layered plug and play capability
- Standardizes model interfacing
- Protects proprietary data / models

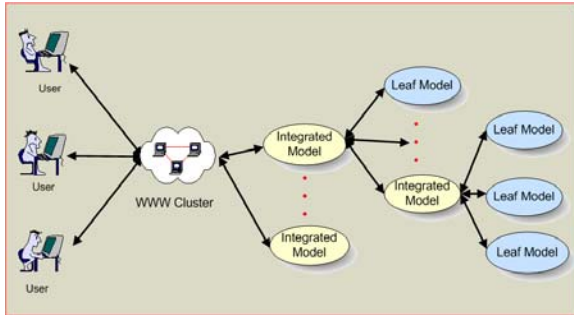


Matching

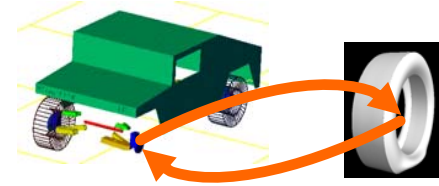


Non-Matching

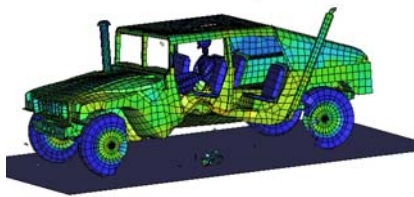
# Overview



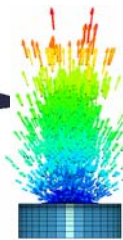
D-Sim



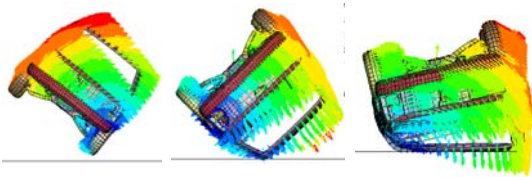
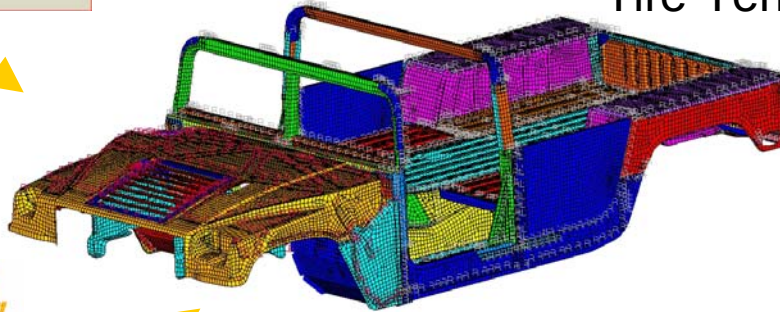
Tire-Terrain Interaction



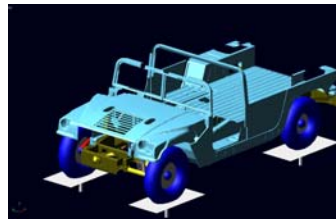
Blast



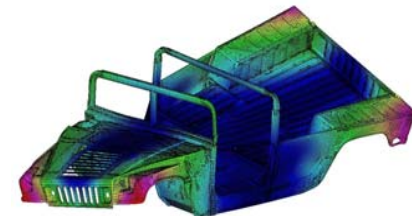
Durability



Crash



Rollover

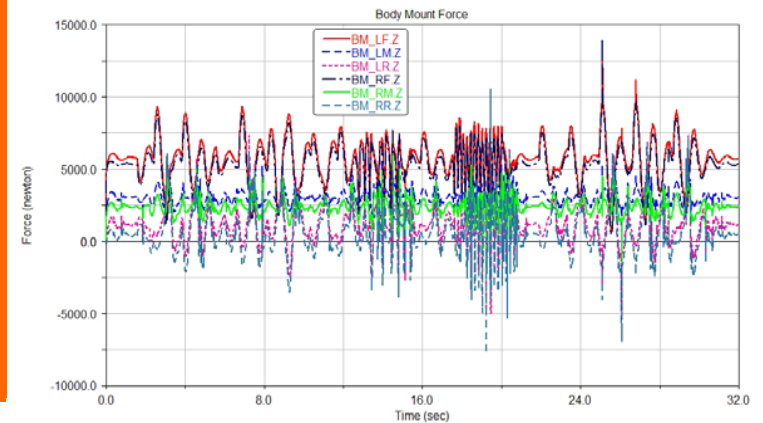


# Durability Road Simulation

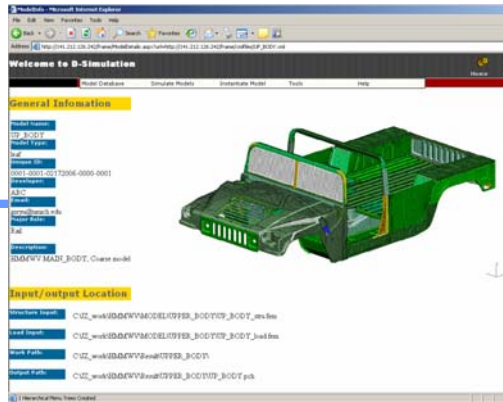
## Durability Road



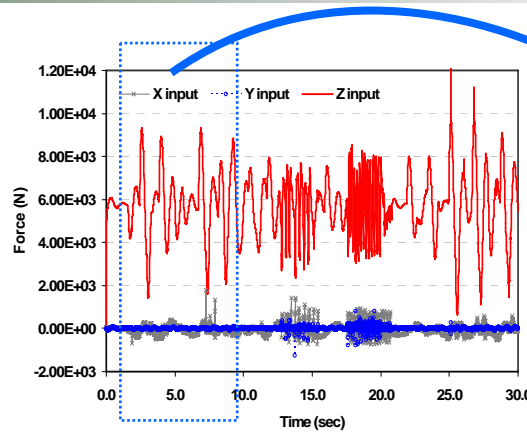
## Computed Body Mount Forces



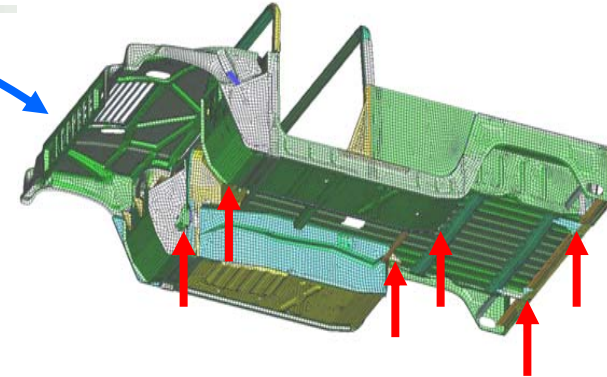
# Gluings Algorithm for Durability



Assembly of Main Body and Hood



Forces computed using ADAMS

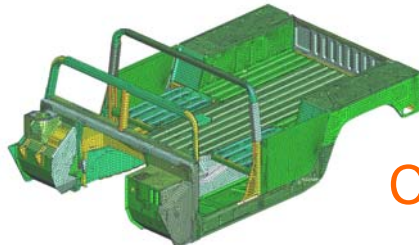


Apply external force at 6 body mounts



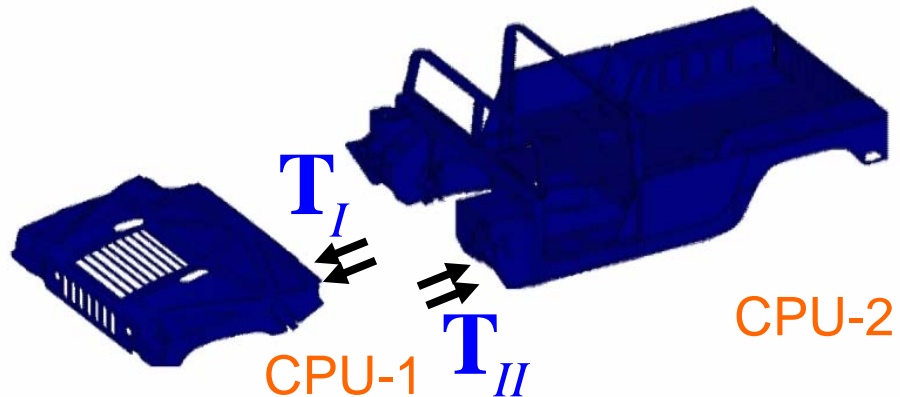
CPU-1

HOOD ASSEMBLY



CPU-2

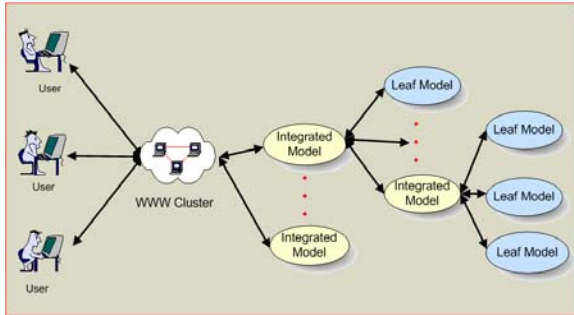
MAIN BODY ASSEMBLY



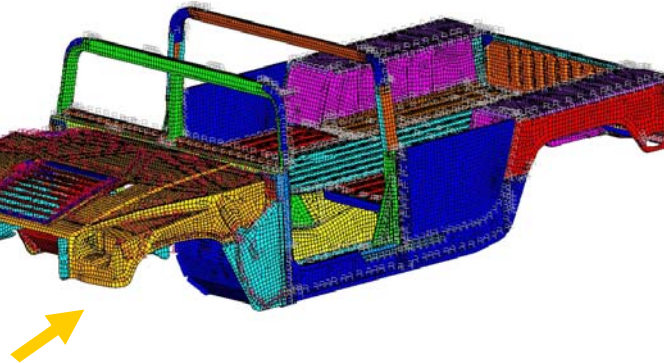
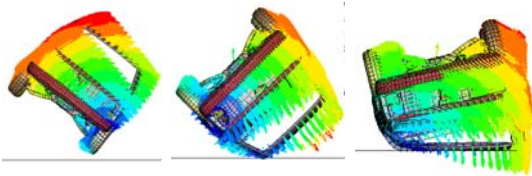
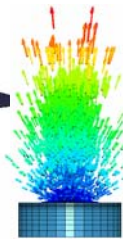
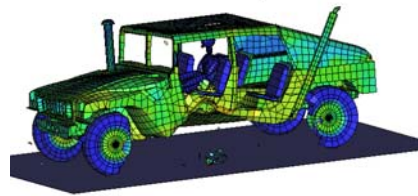
D-Sim Results  
(coupled simulation)



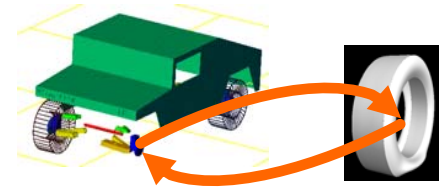
# Overview



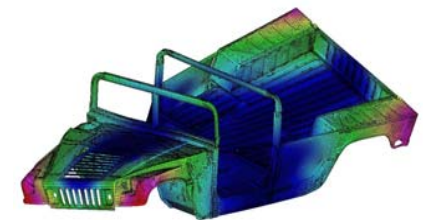
D-Sim



Safety



Terrain Interaction



Durability and Ride

# Safety Applications



Rollover



Crash



Blast



Extreme Terrain



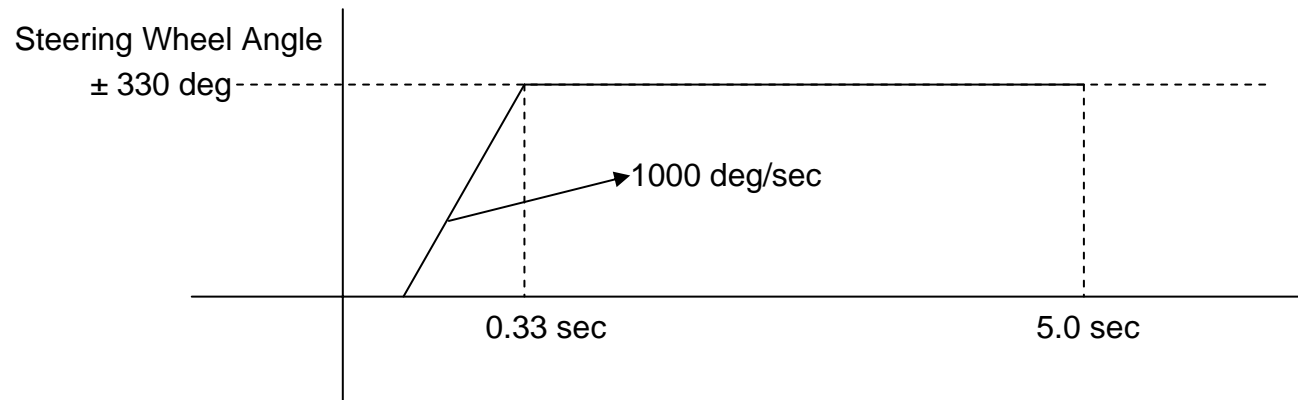
# HMMWV Rollover



# J-Turn Rollover Simulation (Flat Ground)

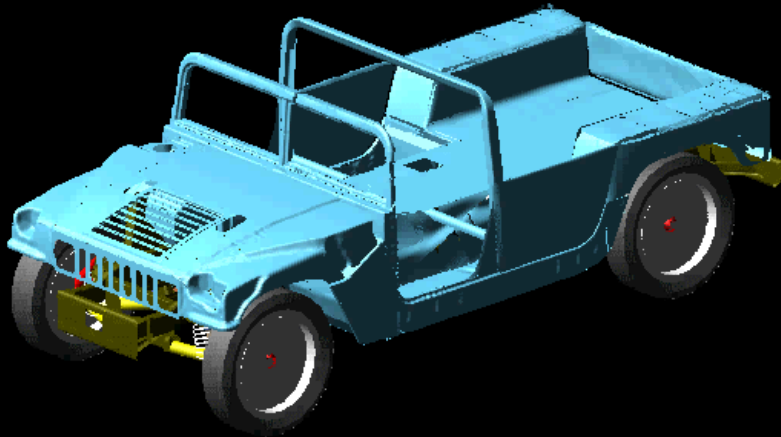
## Driving Conditions

- Modified test protocol
- Initially driven in a straight line
- Initial speed: 10 mph and up
- Test runs for 5 seconds



# J-Turn (Rigid Body Model)

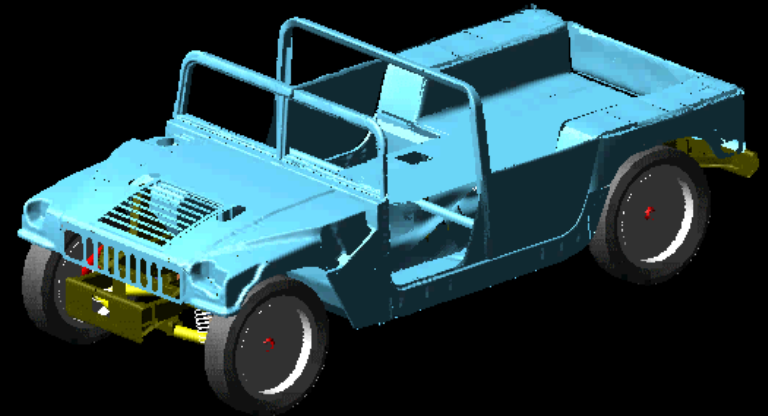
Time= 6.0000 Frame=001



- Predict critical speed range
- Study rollover behavior
- Assess effect of up-armor system
- Design for rollover prevention

Time= 6.0000 Frame=001

**Nominal speed**

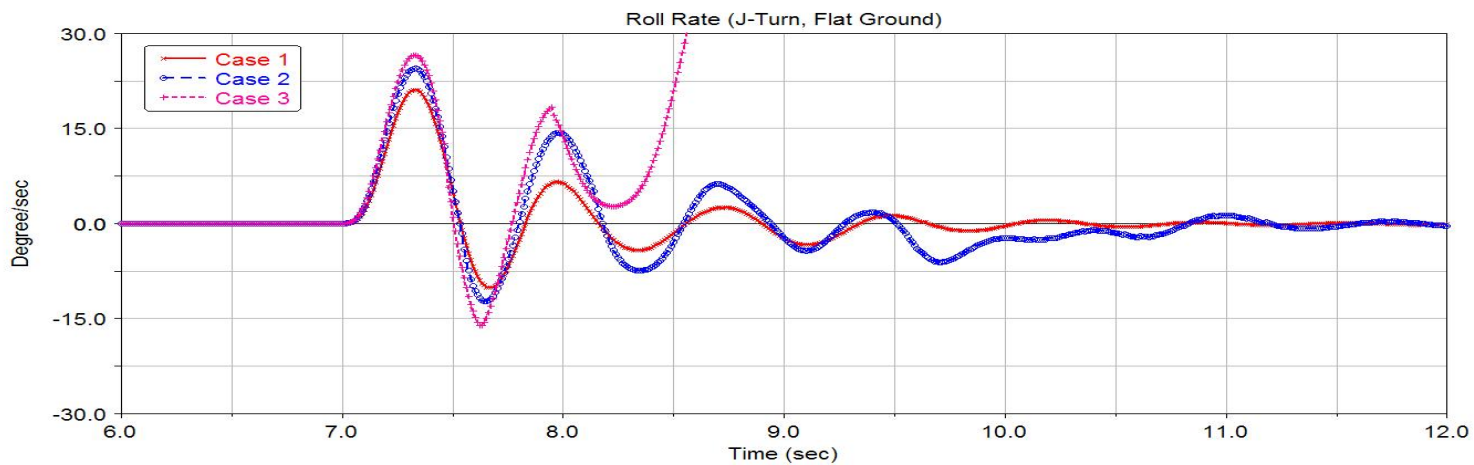
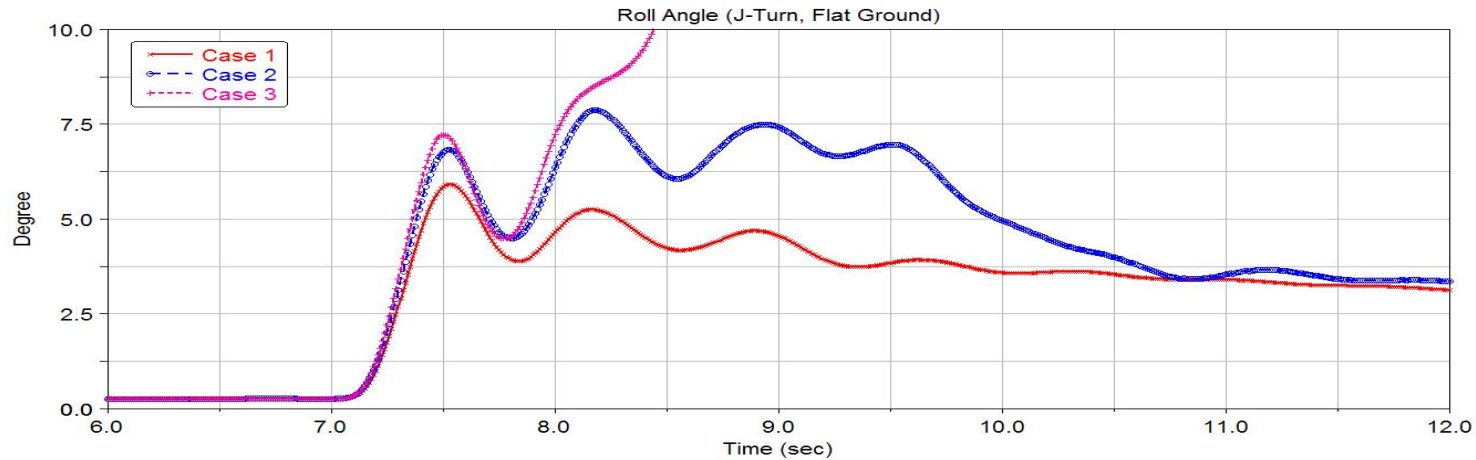


**Nominal speed+ 10 mph**



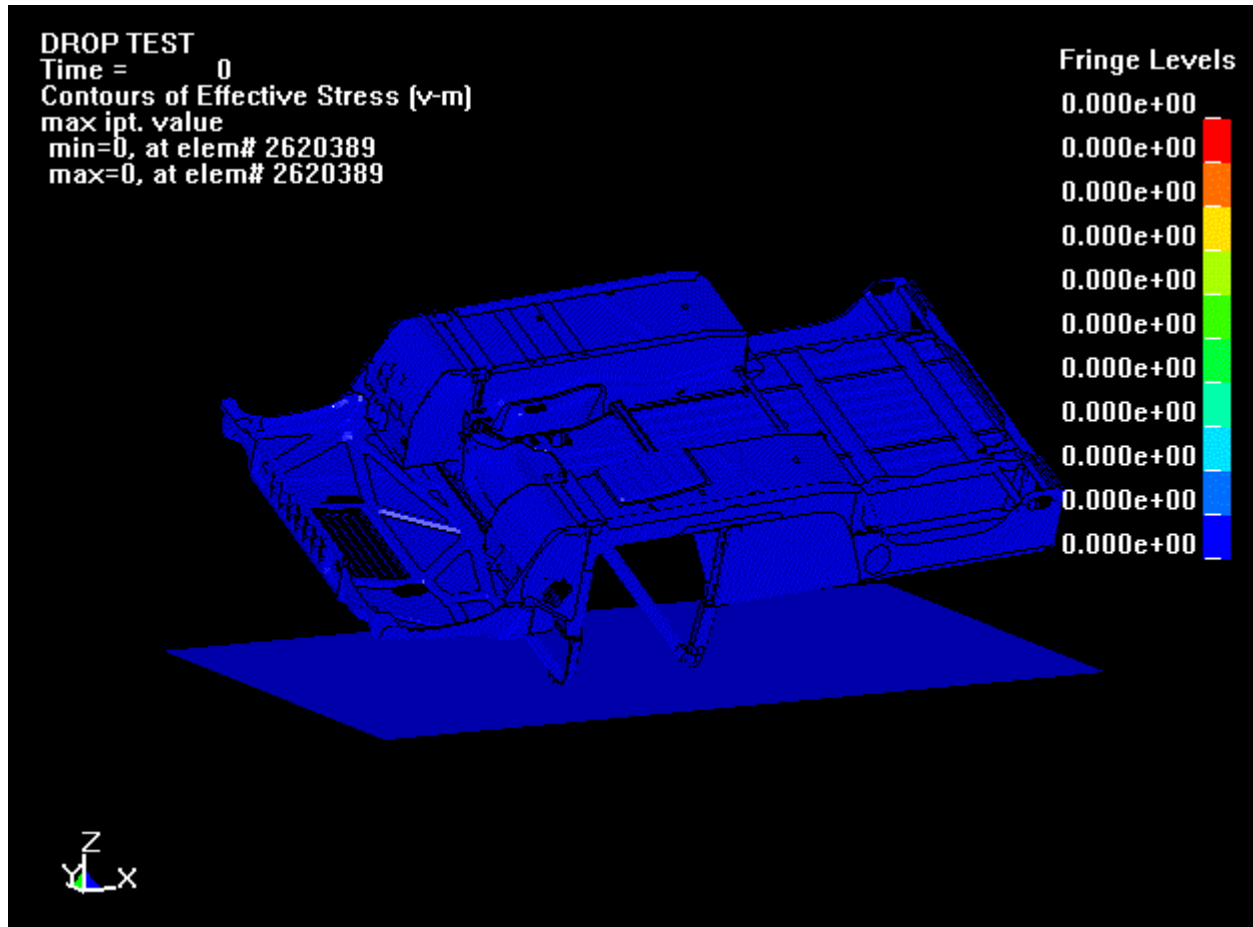


# J-Turn Analysis Results

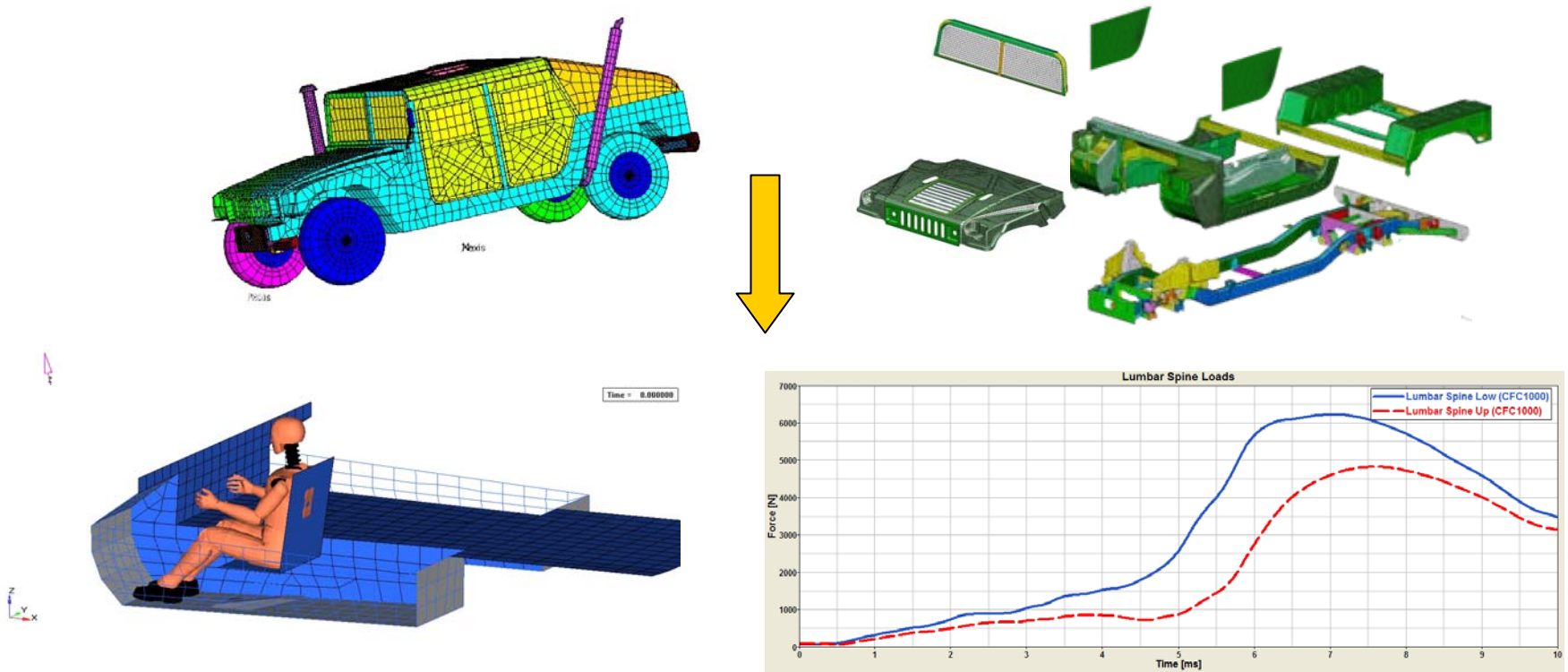


# Roof Strength Analysis

## ➤ Drop Test



# Simulating the Response of Structures and Occupants to Blast Loads



Response of vehicle floor and occupant under blast

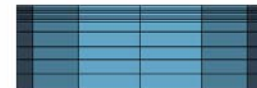
# J-Turn Rollover under a Blast

blast2\_3 Time= 6.0000 Frame=001

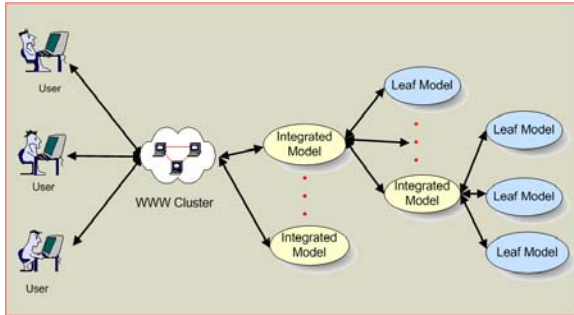


LANDMINE EXPLOSION  
Time = 0  
Vector of Total-velocity  
min=0, at node# 50  
max=0, at node# 581

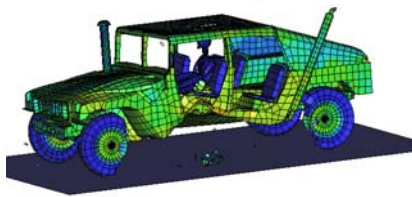
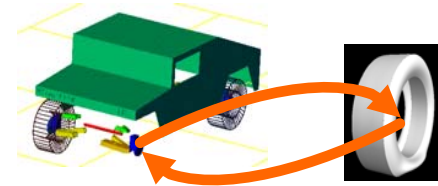
Fringe Levels  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000  
0.000e+000



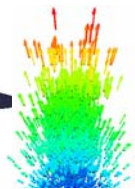
# Overview



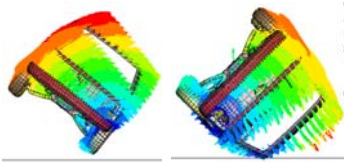
D-Sim



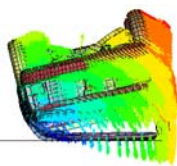
Blast



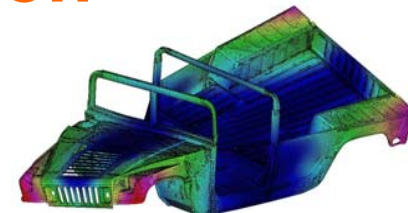
## Tire-Terrain Interaction



Crash



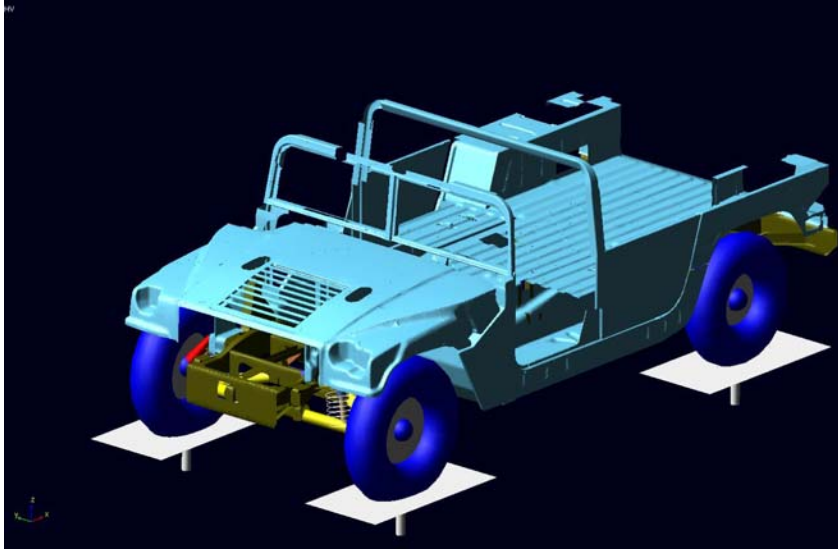
Rollover



Durability



# Extreme Terrain



Sand



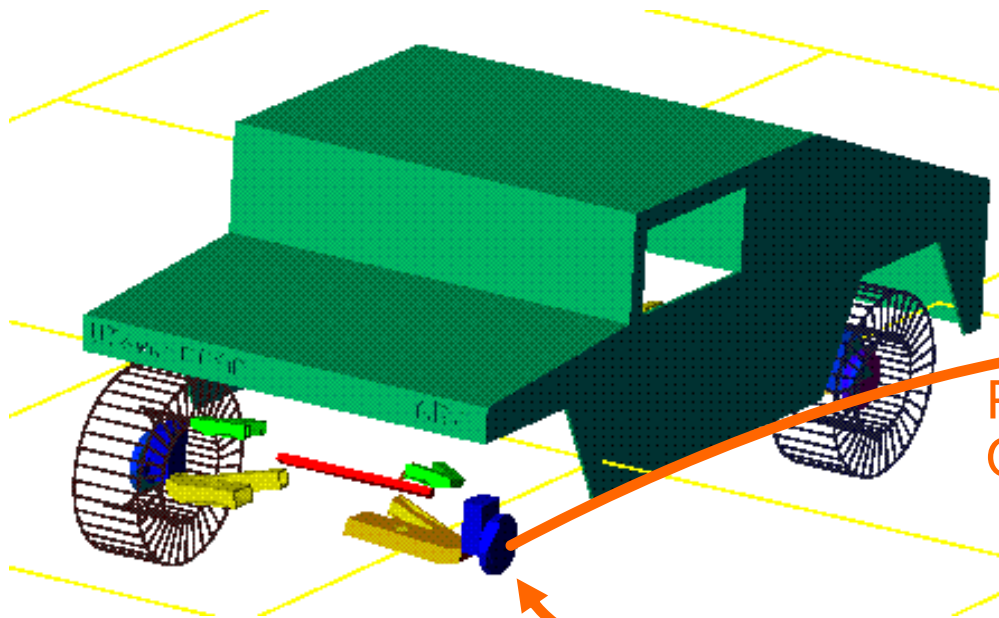
Ice



Snow

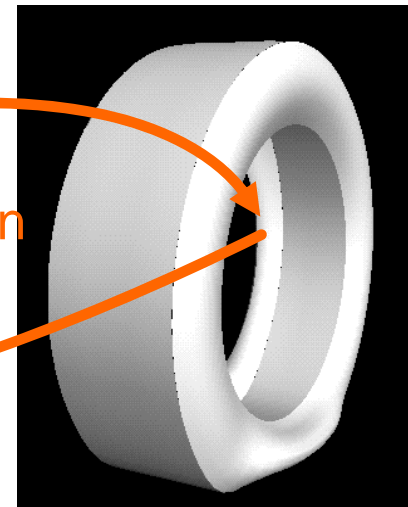
# Tire-Terrain Interaction

- Tire passes forces / moments to vehicle
- Vehicle passes hub position / orientation to tire



Position /  
Orientation

Forces/Moments

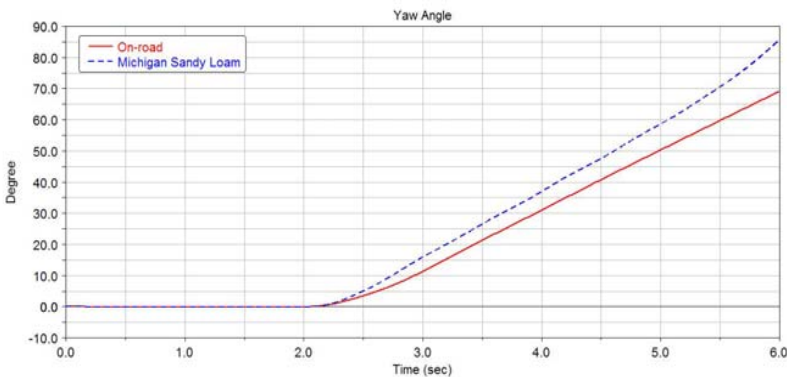
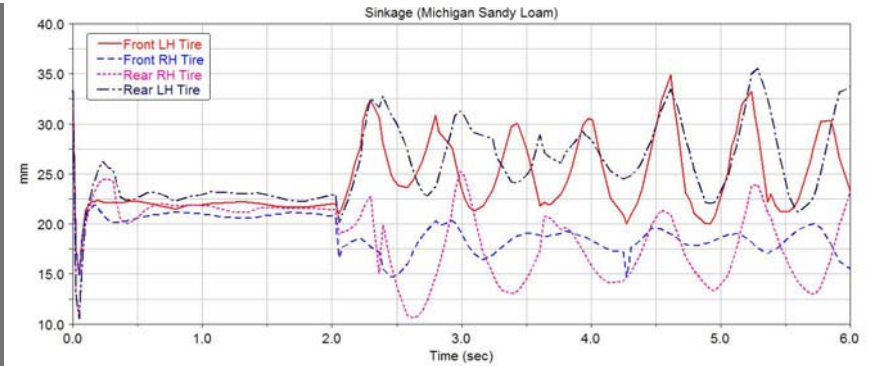


# Vehicle Performance for Off-Road Events

Multiple Runs Time= 0.0000 Frame=001

Michigan  
Loam

On-road



Off-road Maneuver

Automotive Research Center



# Summary

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- Comprehensive, integrated platform for analysis and design to support current and next generation vehicles
- Enabling technologies:
  - General, functional simulation framework
  - Algorithms for coupling different models and simulation codes
  - Algorithms for coupling non-matching interfaces

# Future Developments

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- Continue development of model database
- Incorporate human models
  - Driver perception
  - Assess safety systems
- Expand integration with commercial software
- Verify, validate and update model database using instrumented vehicles
- Simulation-based certification



# Future Developments

